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**APPLICATION
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FOR: MOBILE COMMUNICATION SYSTEM
FOR PERFORMING HAND-OFF
CONTROL BASED ON CHANNEL
STATION DATA

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**MOBILE COMMUNICATION SYSTEM FOR PERFORMING
HAND-OFF CONTROL BASED ON CHANNEL STATION DATA**

BACKGROUND OF THE INVENTION

1. Field of the Invention:

The present invention relates to a mobile communication system, and more particularly to a mobile communication system for switching communication channels between base stations covering respective communication areas as a mobile station moves between the communication areas.

2. Description of the Related Art:

Mobile communication systems have a plurality of radio communication areas, each of a predetermined range, called cells, that cover an entire service area. Mobile stations in the service area can communicate with each other via base stations located in the respective cells. In such a mobile communication system, a channel switching control process is performed to switch base stations for radio communication with a mobile station as the mobile station moves from one cell to another. Such a channel switching control process is referred to as a hand-off control process. There are available two types of hand-off control processes, i.e., a hard hand-off control process with an instantaneous transmission break

and a soft hand-off control process without an instantaneous transmission break.

The hard hand-off control process is simpler but causes an instantaneous transmission break because the present radio channel is cut off before the call is connected to a radio channel to switch to. The soft hand-off control process can switch radio channels without an instantaneous transmission break because the present radio channel remains connected when the call is connected to a radio channel to switch to.

For efficient usage of limited frequency resources, mobile communication systems allow mobile stations to make radio communication with base stations based on either the frequency division multiple access (FDMA) technique, the time division multiple access (TDMA) technique, or the code division multiple access (CDMA) technique. The CDMA mobile communication system often performs the soft hand-off control process free of an instantaneous transmission break using the same frequency in adjacent cells as the cells can easily share the same frequency band by spreading desired signals with respective inherent spreading codes.

Fig. 1 of the accompanying drawings schematically shows a conventional mobile communication system which performs a hand-off control process. As shown in Fig. 1, the conventional mobile communication system has first

and second base stations 11_1 , 11_2 covering respective first and second cells 10_1 , 10_2 as their service areas. First and second base stations 11_1 , 11_2 are connected to a mobile switching center 13 by respective communication channels 12_1 , 12_2 . Mobile switching center 13 is connected to public telephone switching network 15 by inter-switching-center line 14. First and second base stations 11_1 , 11_2 that are located adjacent to each other are connected to each other by inter-base-station line 16. Mobile switching center 13 may include a base station controller for controlling a plurality of base stations. Communication channels 12_1 , 12_2 and inter-base-station line 16 send and receive control information required for the hand-off control process. In the hand-off control process to be described below, it is assumed for illustrative purpose that mobile station 17 present in first cell 10_1 moves into second cell 10_2 .

Fig. 2 of the accompanying drawings schematically shows a sequence of the hand-off control process carried out by the conventional mobile communication system shown in Fig. 1. Mobile station 17 is present in first cell 10_1 , and is communicating with public telephone switching network 15 from first base station 11_1 via communication channel 12_1 , mobile switching center 13, and inter-switching-center line 14 (communication 20). Mobile station 17 periodically measures a reception quality such

as reception levels of radio waves received from
surrounding base stations (measurement 21). If mobile
station 17 detects, based on the measured results, that
the channel quality between first base station 11₁ and
5 mobile station 17 is lowered and the channel quality
between second base station 11₂ and mobile station 17 is
increased, then mobile station 17 sends quality
information 22 representing such channel quality changes
to first base station 11₁ which is master base station
10 for mobile station 17.

When first base station 11₁ receives quality
information 22, first base station 11₁ performs a soft
hand-off control process, and transmits soft hand-off
request 23 to second base station 11₂. Second base
15 station 11₂ assigns an inherent spreading code and sets a
radio channel between itself and mobile station 17.
Mobile station 17 now enters a soft hand-off mode
dominated by first base station 11₁ in which a radio
channel is connected between mobile station 17 and first
20 and second base stations 11₁, 11₂. Mobile station 17
then communicates with mobile switching center 13 via
first and second base stations 11₁, 11₂ (communication
24).

In the soft hand-off mode dominated by first base
25 station 11₁, since mobile switching center 13 recognizes
that mobile station 17 is under the control of first base

station 11₁, downstream user information is transmitted through a radio link from mobile switching center 13 via communication channel 12₁ to first base station 11₁ and then from first base station 11₁ to mobile station 17.

- 5 At the same time, the downstream user information from mobile switching center 13 is transmitted via inter-base-station line 16 from first base station 11₁ to second base station 11₂, from which the downstream user information is also transmitted through a radio link to
- 10 mobile station 17. Mobile station 17 receives the downstream user information from first base station 11₁ and second base station 11₂ by way of diversity reception. Mobile station 17 transmits upstream user information to first base station 11₁ and second base
- 15 station 11₂. The upstream user information received by second base station 11₂ is transmitted via inter-base-station line 16 to first base station 11₁. First base station 11₁ receives the upstream user information by way of diversity reception, and transmits the received
- 20 upstream user information via communication channel 12₁ to mobile switching center 13.

- When mobile station 17 measures the channel quality (measurement 25) and detects that the channel quality between first base station 11₁ and mobile station 17 is
- 25 further lowered and the channel quality between second base station 11₂ and mobile station 17 is sufficient,

mobile station 17 sends quality information 26
representing such channel quality changes to first base
station 11₁.

When first base station 11₁ receives the quality
5 information, first base station 11₁ sends hard hand-off
request 27 to mobile switching center 13 which is master
station for first base station 11₁ in order to shift from
the soft hand-off mode dominated by first base station
11₁ to a soft hand-off mode dominated by second base
10 station 11₂.

In response to hard hand-off request 27 sent from
first base station 11₁, mobile switching center 13
transmits hard hand-off instruction 28 via communication
channels 12₁, 12₂ to first and second base stations 11₁,
15 11₂, thereby recognizing that mobile station 17 has been
brought under the control of second base station 11₂.
Mobile station 17 now enters the soft hand-off mode
dominated by second base station 11₂ in which a radio
channel is connected between mobile station 17 and first
20 and second base stations 11₁, 11₂. Mobile station 17
then communicates with mobile switching center 13 via
first and second base stations 11₁, 11₂ (communication
29).

When mobile station 17 measures the channel quality
25 (measurement 30) and detects that the channel quality
between first base station 11₁ and mobile station 17 is

1
4
sufficiently lowered, mobile station 17 sends quality
information 31 representing such channel quality changes
to second base station 11₂.

5 Having received quality information 31, second base
station 11₂ transmits a soft hand-off cancellation
request 32 via inter-base-station line 16 to first base
station 11₁ that is in the soft hand-off mode, finishes
the soft hand-off mode, and enters a normal communication
mode. Mobile station 17 can now communicate with public
10 telephone switching network 15 via second base station
11₂, communication channel 12₂, mobile switching center
13, and inter-switching-center line 14 (communication
33).

15 In the above conventional mobile communication
system, the inter-base-station line is provided between
the adjacent base stations, and control information about
the soft hand-off control of radio channels between the
base stations and the mobile station and the hard hand-
off control between the base stations and the mobile
20 switching center is sent and received between the base
stations. Therefore, the burden on the mobile switching
center due to the soft hand-off control process can be
reduced.

25 The technical details of the above mobile
communication system are disclosed in Japanese unexamined
patent publication No. 10-145834 on "Method of carrying

out soft hand-off control in mobile communication system,
mobile communication system and radio base station
therefor".

Published Japanese translation of PCT international
5 publication No. 9-511107 on "Semi-hard hand-off in
cellular electric communication system" discloses the
technology of a mobile communication system for
performing semi-hard hand-off control by placing a base
station in an overlapping region covered by adjacent base
10 stations under the control of different mobile switching
centers, which serve as a master station for the base
station placed in the overlapping region.

Fig. 3 of the accompanying drawings schematically
shows an arrangement of the mobile communication system
15 disclosed in the published Japanese translation of PCT
international publication No. 9-511107. As shown in Fig.
3, the mobile communication system has first and second
mobile switching centers 41_1 , 41_2 connected to each other
by switching center channel 40 and also connected to
20 respective first and third base stations 43_1 , 43_3 under
its control by respective communication channels 42_1 ,
 42_2 . Second mobile switching center 41_2 is connected to
public telephone switching network 45 via public network
line 44. First and third base stations 43_1 , 43_3 cover
25 respective areas 46_1 , 46_2 , which have an overlapping
region that is covered by second base station 43_2 .

Second base station 43₂ has, as its master station, first and second mobile switching centers 41₁, 41₂, and is connected thereto by respective communication channels 47₁, 47₂.

5 It is assumed that mobile station 48 has third base station 43₃ as its master station, is communicating with public telephone switching network 45 via second mobile switching center 41₂, and moves successively through the cells covered by second base station 43₂ and first base
10 station 43₁. When mobile station 48 moves from the cell covered by third base station 43₃ to the cell covered by second base station 43₂, a soft hand-off control process is performed while mobile station 48 is being connected to second and third base stations 43₂, 43₃ via
15 communication channels 42₂, 47₂. At this time, second mobile switching center 41₂ as a node receives information by way of diversity reception. As mobile station 48 moves away from third base station 43₃ toward second base station 43₂, the soft hand-off control
20 process is finished, and mobile station 48 has second base station 43₂ as its master station and communicates with public telephone switching network 45 via second mobile switching center 41₂.

25 Mobile station 48 periodically reports measured reception quality to second base station 43₂ as its master station. If second mobile switching center 41₂

detects, based on the report, that mobile station 48 is moving from second base station 43₂ under its own control toward first base station 43₁ under the control of another mobile switching center, then second mobile switching center 41₂ starts a semi-hard hand-off control process. Specifically, second mobile switching center 41₂ detects that first base station 43₁ covering the cell toward which mobile station 48 is moving is under the control of first mobile switching center 41₁ adjacent to second mobile switching center 41₂, and sends a semi-hard hand-off request to first mobile switching center 41₁ via switching center channel 40. First mobile switching center 41₁, which is connected to second base station 43₂ by communication channel 47₁, transmits a semi-hard hand-off response to second mobile switching center 41₂ via switching center channel 40. In response to the semi-hard hand-off reply, second mobile switching center 41₂ disconnects communication channel 47₂ between itself and second base station 43₂. Mobile station 48 now has second base station 43₂ as its master station and communicates with public telephone switching network 45 via first mobile switching center 41₁, switching center channel 40, and second mobile switching center 41₂.

When mobile station 48 further moves toward first base station 43₁ under the control of first mobile switching center 41₁, a soft hand-off control process is

carried out in which mobile station 48 is connected to first and second base stations 43₁, 43₂ via communication channels 42₁, 47₁, and first mobile switching center 41₁ as a node receives information by way of diversity
5 reception.

In the above conventional mobile communication system, the hand-off control process performed when the mobile station moves is a soft hand-off control process without an instantaneous transmission break, rather than
10 a hard hand-off control process with an instantaneous transmission break. Therefore, channels are provided between the base stations for performing the soft hand-off control process, between base station control apparatus, or between the mobile switching centers for
15 sending and receiving user information. When the mobile station continues to move while in communication, the soft hand-off control process is repeated not only between the base stations, but also between the base station control apparatus as master stations for the base
20 stations, and between the mobile switching centers as master stations therefor. When the mobile station further moves while the soft hand-off control process is being performed between the mobile switching centers, the mobile station may move from the service area of home
25 system into the service area of another system.

1 A hand-off control process needs to be performed
between different systems for increasing the quality of
services provided to the users of mobile stations. In
order to carry out such a hand-off control process
5 between different systems, it is necessary to provide
communication channels between mobile switching centers
of one of the systems which control communications of the
mobile station and adjacent mobile switching centers of
the other system. However, attempts to provide
10 communication channels between all adjacent mobile
switching centers of the different systems would result
in a high installation cost.

SUMMARY OF THE INVENTION

15 It is an object of the present invention to provide
a relatively inexpensive mobile communication system
which is capable of performing a hand-off control process
between different systems.

To achieve the above object, a mobile communication
20 system according to the present invention has a mobile
station, a base station, a base station controller, and a
mobile switching center.

The base station is disposed in each of service
areas for performing radio communication with the mobile
25 station positioned in each of service areas.

The base station controller has channel station data indicative of whether there is a channel between a mobile switching center as a master station thereof and another mobile switching center. The base station controller has means for, when a hand-off control process is to be performed via the mobile switching center as the master station while communicating with the mobile terminal through the base station, determining whether the mobile switching center as the master station has a channel connected to the other mobile switching center or not based on the channel station data, and, if the mobile switching center as the master station has a channel connected to the other mobile switching center, requesting a hand-off control process as a process for switching communication channels for communication with the mobile station.

The mobile switching center as the master station of the base station controller performs a hand-off control process between itself and the other mobile switching center when the hand-off control process is requested.

With the above arrangement, the base station controller has channel station data indicative of whether there is a channel between a mobile switching center as a master station thereof and another mobile switching center. When a hand-off control process is to be

performed via the mobile switching center as the master station while communicating with the mobile terminal through the base station, the base station controller determines whether the mobile switching center as the master station has a channel connected to the other mobile switching center or not based on the channel station data. If the mobile switching center as the master station has a channel connected to the other mobile switching center, then the base station controller requests a hand-off control process. The mobile switching center performs a hand-off control process when the hand-off control process is requested.

According to the present invention, another mobile communication system has a mobile station, one or more base stations, one or more base station controllers, and one or more interconnected mobile switching centers.

The one or more base stations are disposed in each of service areas for performing radio communication with the mobile station positioned in each of service areas.

The one or more base station controllers serve as a master station of the one or more base stations and have channel station data indicative of whether there is a channel between a mobile switching center as a master station thereof and another system mobile switching center in another system of different specifications. The one or more base station controllers have means for,

when a hand-off control process is to be performed via the mobile switching center as the master station while communicating with the mobile terminal through the base station during an inter-base-station-controller soft

- 5 hand-off control process, determining whether the mobile switching center as the master station has a channel connected to the other system mobile switching center or not based on the channel station data, and, if the mobile switching center as the master station has a channel
- 10 connected to the other system mobile switching center, requesting an inter-system hand-off control process as a process for switching communication channels between the mobile station and the other system mobile switching center to the mobile switching center as the master
- 15 station, and, if the mobile switching center as the master station does not have a channel connected to the other system mobile switching center, requesting an intra-system hand-off control process between the mobile station and the mobile switching center in a home system.

- 20 The one or more interconnected mobile switching centers serve as a master station of at least one of the one or more base station controllers, for performing the hand-off control process in a home system when the intra-system hand-off control process is requested, at least
- 25 one of the one or more interconnected mobile switching centers having a communication channel connected to the

other system mobile switching center, for performing a predetermined hand-off control process between itself and the other system mobile switching center when the inter-system hand-off control process is requested.

5 With the above arrangement, each of the one or more base station controllers which are disposed adjacent to each other and interconnected has channel station data indicative of whether there is a channel between a mobile switching center as a master station thereof and another
10 system mobile switching center in another system of different specifications. When a hand-off control process is to be performed via the mobile switching center as the master station while communicating with the mobile terminal through the base station during an inter-
15 base-station-controller soft hand-off control process, the one or more base station controllers determine whether the mobile switching center as the master station has a channel connected to the other system mobile switching center or not based on the channel station
20 data. If the mobile switching center as the master station has a channel connected to the other system mobile switching center, the one or more base station controllers request an inter-system hand-off control process as a process for switching communication channels
25 between the mobile station and the other system mobile switching center to the mobile switching center as the

master station. If the mobile switching center as the master station does not have a channel connected to the other system mobile switching center, the one or more base station controllers request an intra-system hand-off control process between the mobile station and the mobile switching center in a home system. At least one of the one or more interconnected mobile switching centers which serve as a master station of the one or more base station controllers has a communication channel between itself and the other system mobile switching center. The one or more mobile switching centers perform a hand-off control process between itself and the other system mobile switching center when the inter-system hand-off control process is requested, and perform the hand-off control process in a home system when the intra-system hand-off control process is requested.

The mobile communication system has a communication channel between only a mobile switching center adjacent to a service area of the other system including an overlay and the other system mobile switching center.

Because a communication channel is provided between only a mobile switching center adjacent to a service area of the other system including an overlay and the other system mobile switching center, the cost of facilities of an inter-system channel required for an inter-system hand-off control process is minimized.

According to another aspect of the present invention, the mobile switching center comprises means for, when the intra-system hand-off control process is requested, selecting a mobile switching center in the home system which has a communication channel connected to the other system mobile switching center, and performing a hand-off control process between itself and the selected mobile switching center.

With the above arrangement, when the intra-system hand-off control process is requested, a mobile switching center in the home system which has a communication channel connected to the other system mobile switching center is selected, and a hand-off control process is performed between itself and the selected mobile switching center. Therefore, when a hand-off control process between the systems is required via the channel through which the mobile station is communicating, the inter-system hand-off control process is carried out, thus simplifying the inter-mobile-switching-center hand-off control process between the systems.

The home system comprises a mobile communication system according to code division multiple access principles.

With the above arrangement, the hand-off control process is performed in the mobile communication system according to code division multiple access principles.

Particularly, a large-scale mobile communication system which has many mobile switching centers allows the same frequency to be used in adjacent cells and hence allows an inter-system hand-off control process to be carried out using pilot signals of the same frequency between cells in different cellular systems. A reduction in the cost of facilities of such a large-scale mobile communication system is highly advantageous.

The above and other objects, features, and advantages of the present invention will apparent from the following description with reference to the accompanying drawings which illustrate examples of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram of a conventional mobile communication system which performs a hand-off control process;

Fig. 2 is a sequence diagram showing a hand-off control sequence of the conventional mobile communication system;

Fig. 3 is a block diagram of a mobile communication system disclosed in published Japanese translation of PCT international publication No. 9-511107;

Fig. 4 is a block diagram of a mobile communication system according to an embodiment of the present invention;

Fig. 5 is a flowchart of a pilot signal receiving process of a mobile station in the mobile communication system according to the embodiment;

Fig. 6 is a diagram showing inter-system channel station data possessed by a first base station controller in the mobile communication system according to the embodiment;

Fig. 7 is a diagram showing inter-system channel station data possessed by a second base station controller in the mobile communication system according to the embodiment;

Fig. 8 is a diagram showing inter-system channel station data possessed by a third base station controller in the mobile communication system according to the embodiment;

Fig. 9 is a diagram showing inter-base-station-controller hand-off control information possessed by the base station controllers in the mobile communication system according to the embodiment;

Fig. 10 is a diagram showing proximity cell information possessed by the base station controllers in the mobile communication system according to the embodiment;

Fig. 11 is a flowchart of a control program of each of the base station controllers in the mobile communication system according to the embodiment;

Fig. 12 a sequence diagram of a former half of an operation sequence of the mobile communication system according to the embodiment; and

Fig. 13 a sequence diagram of a latter half of the operation sequence of the mobile communication system according to the embodiment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Fig. 4 schematically shows a mobile communication system according to an embodiment of the present invention. The mobile communication system according to the embodiment has the service area of a home cellular system and the service area of another cellular system, which are differentiated by system providers, communication principles, channel protocols, and various other different specifications. It is assumed that the home cellular system is a CDMA system and the other system is an analog system.

The service area of the home cellular system has first and second mobile switching centers (MSC) 50₁, 50₂. First MSC 50₁ controls first base station controller (BSC) 51₁ as its slave station, and second MSC 50₂ controls second and third BSCs 51₂, 51₃ as its slave

stations. First BSC 51₁ controls first and second base stations (BS) 52₁, 52₂ as its slave stations, which cover first service area 53₁. Second BSC 51₂ controls third and fourth BSs 52₃, 52₄ as its slave stations, and third
5 BSC 51₃ controls fifth BS 52₅ as its slave station. Third, fourth, and fifth BSs 52₃, 52₄, 52₅ cover second service area 53₂.

Inter-MSC channel 54 is connected between first and second MSCs 50₁, 50₂, and an inter-MSC hard hand-off
10 control process is performed via inter-MSC channel 54. First and second inter-BSC channels 55₁, 55₂ are connected between first and second BSCs 51₁, 51₂ and between second and third BSCs 51₂, 51₃. A BSC soft hand-off control process is performed via first and second
15 inter-BSC channels 55₁, 55₂.

The service area of the other cellular system has other system MSC 56 which controls other system BSC 57 as its slave station. Other system BSC 57 controls Mth BS 58 as its slave station, which covers other system
20 service area 59.

In the other cellular system, a pilot signal having a frequency used by the home cellular system can be transmitted to Mth BS 58 whose service area is positioned close to the home cellular system. Therefore, a mobile
25 station (MS) which is receiving a pilot signal on the CDMA principle in the service area of the home cellular

system can recognize the presence of a pilot signal of the other cellular system.

In the mobile communication system according to the present embodiment, second MSC 50₂ closest of the MSCs in the home cellular system to the service area of the other cellular system and other system MSC 56 closest of the MSCs in the other cellular system to the service area of the home cellular system are connected to each other by inter-system channel 60. An inter-system hard hand-off control process is performed via inter-system channel 60.

Each of the BSCs of the home cellular system possesses inter-system channel station data indicative of whether an MSC as a master station thereof in the home cellular system and an MSC in the other cellular system are connected by an inter-system channel or not. When an MS moving in the service area of the home cellular system enters the service area of the other cellular system for hand-off to the other cellular system, the following process is performed: The BSC which is the master station of the MS checks the inter-system channel station data possessed thereby to determine whether an inter-system channel is connected to the MSC which is the master station of the BSC. If no inter-system channel is connected to the MSC which is the master station of the BSC, then the BSC performs an inter-MSC hard hand-off control process for hand-off to a BS under the control of

an MSC having an inter-system channel. If an inter-system channel is connected to the MSC which is the master station of the BSC, then the BSC performs an inter-system hard hand-off control process via the inter-system channel.

Operation of the mobile communication system according to the embodiment will be described in detail below.

First through fifth BSs 52₁ - 52₅ and Mth BS 58 periodically transmit pilot signals to the BSs under their control. Since the home cellular system is a CDMA system, the pilot signals are spread using spreading codes that are different in the respective BSs, the pilot signals which have the same frequency can be used in adjacent areas. The pilot signals are different for the respective BSs, and comprise respective cell identifiers (ID) under the control of the BSs for identifying the respective BSs.

Each of the BSs which receive the pilot signals has a central processing unit (CPU) for performing a predetermined reception process according to a control program that is stored in a storage unit such as a read-only memory (ROM).

Fig. 5 shows a pilot signal receiving process performed by an MS in the mobile communication system according to the embodiment. In step 70 shown in Fig. 5,

the MS monitors pilot signals received from a plurality of respective BSs. If the MS detects a pilot signal from any one of the BSs in step 70, then the MS despreads the pilot signal with a predetermined spreading code to

5 determine which BS has transmitted the pilot signal, and measures the received intensity of the pilot signal. In step 72, the MS determines whether the measured received intensity is in excess of a given level or not. If the measured received intensity is in excess of the given
10 level in step 72, then the MS transmits a pilot signal intensity report to the BS which has sent the received pilot signal including all pilot numbers of the pilot signals which MS may receive at that time. Thereafter, the MS monitors pilot signals from the respective BSs
15 again. If the measured received intensity is not in excess of the given level in step 72, then the MS monitors pilot signals from the respective BSs again.

Operation of the BSCs in the mobile communication system according to the embodiment will be described
20 below.

As described above, each of the BSCs possesses inter-system channel station data indicative of whether an MSC as a master station thereof and an MSC in the other cellular system are connected by an inter-system
25 channel or not. The inter-system channel station data are registered in the respective BSCs in association with

the respective cell IDs for the BSs under the control of the BSCs to identify the cells of the adjacent other system.

Fig. 6 shows inter-system channel station data possessed by first BSC 51₁ in the mobile communication system according to the embodiment. The inter-system channel station data shown in Fig. 6 indicate cells having respective cell IDS "m" - "n", in the vicinity of a BS under the control of first BSC 51₁, and station data values representing whether there is an inter-system channel between MSCs as master stations of those cells and first MSC 50₁ as the master station of first BSC 51₁. In the illustrated embodiment, since Mth BS 58 is not included in a cell in the vicinity of first BSC 51₁ and there is no inter-system channel between first BSC 51₁ and other system MSCs, all the station data values are set to "0" indicating that there is no inter-system channel.

Fig. 7 shows inter-system channel station data possessed by second BSC 51₂ in the mobile communication system according to the embodiment. The inter-system channel station data shown in Fig. 7 indicate cells having respective cell IDS "p" - "q", in the vicinity of a BS under the control of second BSC 51₂, and station data values representing whether there is an inter-system channel between MSCs as master stations of those cells

and second MSC 50₂ as the master station of second BSC 51₂. In the illustrated embodiment, second MSC 50₂ as the master station of second BSC 51₂ is connected to the other system MSC 56 by the inter-system channel 60.

5 However, since there is no cell under the control of the other system MSC 56 in the vicinity of second BSC 51₂, all the station data values are set to "0" indicating that there is no inter-system channel.

Fig. 8 shows inter-system channel station data
10 possessed by third BSC 51₃ in the mobile communication system according to the embodiment. The inter-system channel station data shown in Fig. 8 indicate cells having respective cell IDS "M" - "z", in the vicinity of a BS under the control of third BSC 51₃, and station data
15 values representing whether there is an inter-system channel between MSCs as master stations of those cells and second MSC 50₂ as the master station of third BSC 51₃. In the illustrated embodiment, second MSC 50₂ as the master station of third BSC 51₃ is connected to the
20 other system MSC 56 by the inter-system channel 60. Since there is a cell ID "M" identifying Mth BS 58 under the control of the other system MSC 56 in the vicinity of third BSC 51₃, the station data value indicative of whether there is an inter-system channel corresponding to
25 the cell ID "M" is set to "1", and the station data

values corresponding to the other cell IDs are set to "0" indicating that there is no inter-system channel.

Based on a pilot signal intensity report from an MS as shown in Fig. 5, a BSC having such inter-system
5 channel station data performs an inter-MSC hard hand-off control process for hand-off in the home cellular system and an inter-system hard hand-off control process for hand-off to the other cellular system. Such a BSC carries out the hand-off control processes based on
10 inter-BSC hand-off control information and proximity cell information of BSs under its control, in addition to the above inter-system channel station data.

Fig. 9 shows inter-BSC hand-off control information
80 possessed by the BSCs in the mobile communication
15 system according to the embodiment. As shown in Fig. 9, the inter-BSC hand-off control information 80 possessed by the BSCs includes, for respective communication paths managed by the BSCs, base stations 81 communicating with MS 61 in communication modes including a soft hand-off
20 control mode, BSCs 82 as respective master stations of those base stations, and hand-off information 83 representing received intensities of radio waves and whether the BSCs dominate a soft hand-off control process or not.

25 Fig. 10 shows proximity cell information 85 possessed by the BSCs in the mobile communication system

according to the embodiment. As shown in Fig. 10, the proximity cell information 85 possessed by the BSCs includes pilot numbers 86 corresponding to respective cell IDs 87 for identifying cells adjacent to base stations under the control of the BSCs, and system identifiers 88 corresponding to respective cell IDs 87 for indicating whether adjacent cells belong to the home cellular system or the other cellular system.

Each of the BSCs has a CPU (not shown) for executing the above control process according to a control program that is stored in a storage unit such as a ROM.

Fig. 11 shows a control program of each of the BSCs in the mobile communication system according to the embodiment. When a BSC receives a pilot signal intensity report from the MS which has received pilot signals periodically transmitted from BSs under the control of the BSC in an established communication path, the BSC analyzes the pilot signal intensity report in step 90. Specifically, the BSC refers to the proximity cell information shown in Fig. 10 to convert pilot numbers indicated by the pilot signal intensity report into cell IDs and recognizes whether the cells belong to the home cellular system or the other cellular system based on the system identifiers.

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If the proximity cell information possessed by the BSC does not include a pilot number searched for, then the BSC refers to the registered inter-BSC hand-off control information shown in Fig. 9 to look for a BSC which is the master station of the MS that is in communication modes including the soft hand-off mode in the communication path. If there are a plurality of BSCs that are the master station of the MS that is in communication modes including a soft hand-off mode, then the BSC selects an optimum one of the BSCs based on the received intensity of the radio wave from the stored inter-BSC hand-off control information corresponding to the BSCs. The BSC transmits a pilot signal intensity report analysis request to the selected BSC. The BSC which has received the pilot signal intensity report analysis request refers to the proximity cell information thereof based on the indicated pilot number, converts the pilot number into a cell ID, and determines whether the cell ID belongs to home cellular system or not based on the system identifier. If the cell ID belongs to the other cellular system, then the BSC reads inter-system channel station data, extracts information as to whether there is an inter-system channel between an MSC which is the master station of the cell of the other cellular system and an MSC which is the master station of the BSC, and returns the extracted information together with the

converted cell ID as a pilot signal intensity report analysis result to the BSC that has transmitted the pilot signal intensity report analysis request.

Based on the received pilot signal intensity report analysis result, the BSC determines whether the received pilot signal intensity report includes a cell ID belonging to the other cellular system or not in step 91. If the received pilot signal intensity report includes at least one cell ID belonging to the other cellular system in step 91, then the BSC determines whether the received intensity of the pilot signal that is indicated by the pilot signal intensity report is in excess of a predetermined level, which is given as a threshold for performing an inter-system hand-off control process, or not in step 92.

If the received intensity is in excess of the predetermined level in step 92, then the BSC searches the inter-system channel station data shown in Figs. 6 through 9 for the cell ID converted based on the pilot signal intensity report analysis result in step 93. Then, in step 94, the BSC determines whether the cell ID converted based on the pilot signal intensity report analysis result is present in the inter-system channel station data held thereby or not. If the cell ID converted based on the pilot signal intensity report analysis result is present in the inter-system channel

station data held thereby in step S94, then the BSC decides that the MSC which is the master station of the BSC has an inter-system channel connected to an MSC of the other cellular system. In step S95, the BSC performs
5 an inter-system hard hand-off control process for hand-off to the other cellular system. Thereafter, the above sequence of the control process is put to an end.

If the cell ID converted based on the pilot signal intensity report analysis result is not present in the
10 inter-system channel station data held by the BSC in step 94, then the BSC performs an inter-MSC hard hand-off control process. Specifically, in step 96, the BSC determines, as a hand-off destination, the MSC having an inter-system channel connected to an MSC which is the
15 master station of a BS in the other cellular system converted based on the pilot signal intensity report analysis result and also having a cell in a best radio wave environment. Then, the BSC carries out an inter-MSC hard hand-off control process in step 97, after which the
20 above sequence of the control process is put to an end.

If the received pilot signal intensity report includes only a cell ID belonging to home cellular system based on the pilot signal intensity report analysis result in step 91, or if the received intensity is not in
25 excess of the predetermined level in step 92, then the BSC performs a normal hand-off control process.

Thereafter, the above sequence of the control process is put to an end.

Operation of the mobile communication system according to the embodiment will specifically be
5 described below with reference to Figs. 12 and 13.

Figs. 12 and 13 show an operation sequence of the mobile communication system according to the embodiment. It is assumed that, as shown in Fig. 4, after MS 61 has made a call to a party accommodated in a public telephone
10 network (not shown) connected to first MSC 50₁ under the control of first BS 52₁, MS 61 moves in the direction indicated by the broken-line arrow 100 successively under the control of 1st BS 52₁, third BS 52₃, fourth BS 52₄, and fifth BS 52₅ while keeping the communication with the
15 called party. During the communication while MS 61 is thus moving, an inter-BSC soft hand-off control process is performed between BSCs via first and second inter-BSC channels 55₁, 55₂. As a result, communication path 101 is established under the control of fifth BS 52₅.

20 As described above with reference to Fig. 5, MS 61 periodically receives pilot signals transmitted from surrounding BSs and measures the intensities of the received pilot signals. As MS 61 further moves from the control of fifth BS 52₅ into the control of Mth BS 58 in
25 the other cellular system, the received intensity of the pilot signal transmitted from Mth BS 58 increases. When

the received intensity exceeds a predetermined level,
then MS 61 transmits a pilot signal intensity report
having the pilot number of Mth BS 58 which is included in
the pilot signal to fifth BS 52₅ in the home cellular
5 system in step 102.

The pilot signal intensity report received by fifth
BS 52₅ is transferred to first MSC 50₁ which has been
called by MS 61 and manages communication path 101, via
third BSC 51₃ and second BSC 51₂.

10 First BSC 51₁ analyzes the received pilot signal
intensity report as indicated by step 90 shown in Fig.
11. Specifically, as described above with reference to
Fig. 11, first BSC 51₁ checks the proximity cell
information held thereby as shown in Fig. 10 in order to
15 convert the pilot numbers indicated by the pilot signal
intensity report into a cell ID. Since first BSC 51₁
does not have fifth BSC 51₅, first BSC 51₁ refers to the
registered inter-BSC hand-off control information as
shown in Fig. 9 to look for a BSC which is the master
20 station of the MS that is in communication modes
including the soft hand-off mode in the communication
path 101. In this case, since first BSC 51₁ and third
BSC 51₃ communicates with MS 61 in the soft hand-off mode
and in view of the received intensity of the radio wave
25 and the hand-off information indicating that the soft
hand-off destination is fifth BS 52₅, third BSC 51₃ which

is the master station of fifth BS 52₅ is selected. First BSC 51₁ transmits a pilot signal intensity report analysis request to selected third BSC 51₃ in step 103.

Third BSC 51₃ which has received the pilot signal intensity report analysis request converts the indicated pilot numbers into a corresponding cell ID based on the proximity cell information held thereby. Furthermore, third BSC 51₃ recognizes whether the cell ID converted based on the proximity cell information belongs to the home cellular system or not based on the system identifier. The inter-system channel station data possessed by third BSC 51₃ indicates that inter-system channel 60 is present between other system MSC 56 which is the master station of Mth BS 58, as shown in Fig. 8, and second MSC 50₂ which is the master station of third BSC 51₃. In step 104, inter-system channel presence/absence information which is "1" indicating the presence of inter-system channel 60 is transmitted as a pilot signal intensity report analysis result, together with the converted cell ID of Mth BS 58, to first BSC 51₁ which has transmitted the pilot signal intensity report analysis request.

Having received the pilot signal intensity report analysis result from third BSC 51₃, first BSC 51₁ determines whether the received pilot signal intensity report includes only a cell ID of the home cellular

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system or not from the pilot signal intensity report analysis result, as indicated by step 91 in Fig. 11. Since the cell ID of Mth BS 58 in the other cellular system is contained, first BSC 51₁ determines whether the received intensity of the pilot signal from Mth BS 58 is in excess of a predetermined level for inter-system hand-off or not, as indicated by step 92 in Fig. 11. If the received intensity of the pilot signal from Mth BS 58 is in excess of the predetermined level, then first BSC 51₁ searches the inter-system channel station data shown in Fig. 6 which is possessed thereby, for the cell ID of Mth BS 58 in the other cellular system which is to serve as a hand-off destination, in step 105. As shown in Fig. 6, first MSC 50₁ which is the master station of first BSC 51₁ sees if it has an inter-system channel between itself and the other cellular system, and determines whether an inter-system hand-off control process is to be carried out or not in step 106. Since first MSC 50₁ does not have an inter-system channel between itself and the other cellular system, first BSC 51₁ performs an inter-MSC hand-off control process. As indicated by step 96 in Fig. 11, first BSC 51₁ determines, as a hand-off destination, the MSC having an inter-system channel connected to an MSC which is the master station of a BS in the other cellular system converted based on the pilot signal intensity report analysis result and also having a

cell in a best radio wave environment. In this embodiment, fifth BS 52₅ under the control of second MSC 50₂ is selected. Therefore, in order to carry out an inter-MSC hard hand-off control process, first BSC 51₁ transmits an inter-MSC hard hand-off request for fifth BS 52₅ to first MSC 50₁ which is the master station thereof, in step 107.

First MSC 50₁ which has received the inter-MSC hard hand-off request from first BSC 51₁ performs an inter-MSC hard hand-off control process between itself and second MSC 50₂ which is the master station of third BSC 51₃ in step 108.

Specifically, first MSC 50₁ transmits a hand-off request 109 via inter-MSC channel 54 to second MSC 50₂. Second MSC 50₂ transfers hand-off request 109 as hand-off request 110 to third BSC 51₃ which is a hand-off destination. Third BSC 51₃ sends a channel setting request 111 for setting another communication path different from communication path 101 to fifth BS 52₅, and sends hand-off reply 112 to second MSC 50₂. Second MSC 50₂ sends hand-off reply 112 as hand-off reply 113 to first MSC 50₁. Having received hand-off reply 113, first MSC 50₁ transmits inter-switching-center hard hand-off reply 114 to first BSC 51₁ which has transmitted the inter-switching-center hard hand-off request.

First BSC 51₁ which has received inter-switching-center hard hand-off reply 114 from first MSC 50₁ which is the master station thereof sends hand-off execution instruction 115 via the communication path 101 to MS 61.

5 MS 61 which has received hand-off execution instruction 115 makes a given hand-off execution preparatory action therein, and thereafter sends hand-off completion report 116 via communication path 101 to first BSC 51₁.

10 First BSC 51₁ which has received hand-off completion report 116 from MS 61 sends hand-off start report 117 to first MSC 50₁.

Based on channel setting request 111 sent from third BSC 51₃ to fifth BS 52₅ and hand-off execution instruction 115 sent to MS 61, a new channel transfer process 118 is completed between MS 61 and third BSC 51₃ via fifth BS 52₅. Then, third BSC 51₃ transmits a hand-off completion report 119 to second MSC 50₂, which then sends hand-off completion report 119 as hand-off completion report 120 to first MSC 50₁.

20 Having received hand-off completion report 120, first MSC 50₁ transmits an old channel cancellation request 1221 via communication path 101 to first BSC 51₁, second BSC 51₂, third BSC 51₃, and fifth BSC 51₅,
25 requesting the cancellation of communication path 101.

Thereafter, MS 61 communicates with a channel that is newly assigned between itself and fifth BS 52₅, and there is established new communication path 122 via first MSC 50₁, second MSC 50₂, third BSC 51₃, and fifth BS 52₅.

5 In this manner, new communication path 122 is established after the inter-switching-center hard hand-off control process is completed. As MS 61 further moves in the direction indicated by the arrow 100, when the pilot signal sent from Mth BS 58 in the other cellular
10 system and received by MS 61 exceeds a certain level, MS 61 transmits gain a pilot signal intensity report including the pilot numbers of Mth BS 58 to fifth BS 52₅ in the home cellular system in step 130.

The pilot signal intensity report received by fifth
15 BS 52₅ is transferred to third BSC 51₃ which manages communication path 122 connected to MS 61.

Third BSC 51₃ analyzes the received pilot signal intensity report. Specifically, as described above with reference to Fig. 11, third BSC 51₃ searches the
20 proximity cell information held thereby as shown in Fig. 10 to convert the pilot numbers indicated by the pilot signal intensity report into a cell ID. Since third BSC 51₃ has fifth BS 52₅, third BSC 51₃ extracts the pilot numbers from the pilot signal intensity report, and
25 converts the pilot numbers into a corresponding cell ID. Third BSC 51₃ then recognizes whether the cell ID

converted from the pilot signal intensity report belongs to home cellular system or not based on the system identifier. The inter-system channel station data possessed by third BSC 51₃ indicates that inter-system channel 60 is present between other system MSC 56 which is the master station of Mth BS 58, as shown in Fig. 8, and second MSC 50₂ which is the master station of third BSC 51₃. In step 131, third BSC 51₃ extracts inter-system channel presence/absence information which is "1" indicating the presence of inter-system channel 60. In step 132, third BSC 51₃ determines whether an inter-system hand-off control process is to be carried out or not based on the inter-system channel presence/absence information. In this embodiment, the extracted inter-system channel presence/absence information indicates that inter-system channel 60 is present between other system MSC 56 which is the master station of Mth BS 58 and second MSC 50₂ which is the master station of third BSC 51₃. Therefore, third BSC 51₃ decides that an inter-system hand-off control process be carried out.

Then, third BSC 51₃ transmits inter-system hand-off request 133 for hand-off to Mth BS 58 in the other cellular system to second MSC 50₂ which is the master station of third BSC 51₃. Having received inter-system hand-off request 133, second MSC 50₂ performs an inter-

system hand-off control process between itself and other system BSC 57 in the other cellular system in step 134.

Specifically, second MSC 50₂ sends an inter-system hand-off request 135 via inter-system channel 60 to other system MSC 56 in the other cellular system. Having received inter-system hand-off request 135, other system MSC 56 makes a given inter-system hand-off control process preparatory action for other system BSC 57 and Mth BS 58 under its control, and thereafter sends inter-system hand-off reply 136 via inter-system channel 60 to second MSC 50₂.

Second MSC 50₂ sends inter-system hand-off reply 136 as other system hand-off reply 137 to third BSC 51₃ which has transmitted inter-system hand-off request 133.

Third BSC 51₃ sends hand-off execution instruction 134 to fifth BS 52₅ under its control. Fifth BS 52₅ sends hand-off execution instruction 134 to MS 61.

Having received hand-off execution instruction 134, MS 61 makes a given hand-off execution preparatory action therein, and thereafter sends hand-off completion report 139 via fifth BS 52₅ to third BSC 51₃.

Third BSC 51₃ which has received hand-off completion report 139 from MS 61 sends hand-off start report 140 to second MSC 50₂.

Second MSC 50₂ transmits call disconnecting request 141 via communication path 122 connected as shown in Fig.

12 to third BSC 51₃ and fifth BS 52₅, and also transmits
call disconnecting request 142 to first MSC 50₁,
disconnecting communication path 122. The hand-off
control process for hand-off to Mth BS 58 in the other
5 cellular system is now completed, after which MS 61
performs mobile communications in the other cellular
system.

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The mobile communication system according to the
present embodiment, as described above, includes cellular
10 systems each having MSCs which controls BSCs and BSs. At
least one of the MSC in one cellular system (home
cellular system) and an MSC in the other cellular system
are interconnected by an inter-system channel. Each of
the BSCs in the home cellular system has inter-system
15 channel station data indicative of whether there is an
inter-system channel connected between the MSC as the
master station thereof and the MSC in the other cellular
system. When a MS moving in the service area of the home
cellular system enters the service area of the other
20 cellular system and performs hand-off to the other
cellular system, the BSC which is the master station of
the MS checks the inter-system channel station data
possessed thereby. If there is no inter-system channel
connected between the MSC as the master station thereof
25 and the MSC in the other cellular system, then an inter-
MSC hard hand-off control process is carried out for

hand-off to a BS under the control of an MSC which has an inter-system channel.

5 If there is an inter-system channel connected between the MSC as the master station thereof and the MSC in the other cellular system, then an inter-system hard hand-off control process is carried out for hand-off via the inter-system channel. Thus, in order to carry out an inter-system hard hand-off control process, it is only necessary to connect at least one of the MSC in the home cellular system and an MSC in the other cellular system with an inter-system channel. Inasmuch as it is not necessary to provide all adjacent MSCs in the different cellular systems with communication channels, the cost of facilities of the mobile communication system is greatly reduced. Particularly, a large-scale CDMA mobile communication system which has many MSCs allows the same frequency to be used in adjacent cells and hence allows an inter-system hand-off control process to be carried out using pilot signals of the same frequency between cells in different cellular systems. A reduction in the cost of facilities of such a large-scale CDMA mobile communication system is highly advantageous. The inter-system channel between the home and other cellular systems is connected only between MSCs adjacent to the service area of the other cellular system including an overlay. The cost of facilities of the inter-system

channel required for the inter-system hand-off control process is thus minimized.

While the CDMA mobile communication system has been described in the above embodiment, the principles of the present invention are also applicable to other mobile communication systems such as TDMA and FDMA mobile communication systems which allow a hand-off control process.

In the above embodiment, a hand-off control process has been described as being performed between systems of different system providers. However, the principles of the present invention are also applicable to a hand-off control process between MSCs in one system. In such an application, the cost of facilities of inter-MSC channels can greatly be reduced.

While a preferred embodiment of the present invention has been described using specific terms, such description is for illustrative purposes only, and it is to be understood that changes and variations may be made without departing from the spirit or scope of the following claims.